

WHAT IS CLAIMED IS:

1. An optical low-pass filter comprising:

at least one birefringence plate which is made of
a uniaxial single crystal that causes birefringence of
incoming rays and has a refractive index difference of
not less than 0.02 for ordinary and extraordinary rays,
wherein said filter satisfies at least one of:

$10^{\circ} < \theta < 27^{\circ}$... (1)

$61^{\circ} < \theta < 80^{\circ}$... (2)

where θ is the angle an optic axis of said at least one
birefringence plate makes with a normal to a surface of
said at least one birefringence plate.

2. A filter according to claim 1, wherein said at
least one birefringence plate is made of lithium
niobate.

3. A filter according to claim 1, further
comprising:

a first birefringence plate made of a uniaxial
single crystal; and

a second birefringence plate made of a uniaxial
single crystal,

wherein an orthogonal projection of an optic axis
of said first birefringence plate onto an entrance or
exit surface and an orthogonal projection of an optic
axis of said second birefringence plate onto the

entrance or exit surface point to different directions.

4. A filter according to claim 3, wherein the
orthogonal projection of the optic axis of said first
5 birefringence plate onto the entrance or exit surface
and the orthogonal projection of the optic axis of said
second birefringence plate onto the entrance or exit
surface make substantially 45° .

10 5. A filter according to claim 1, further
comprising:

a plurality of plane-parallel plates including
said at least one birefringence plate,

15 wherein when said plurality of plane-parallel
plates are adhered via an adhesive, a dielectric thin
film having an anti-reflection effect of rays in a
visible wavelength range at an interface between the
adhesive and said birefringence plate is added to the
surface of said birefringence plate.

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6. An image sensing unit comprising:

an image sensing element; and

25 an optical low-pass filter of claim 1, which is
inserted in an optical path of photographing light
guided to said image sensing element, and causes
birefringence of the photographing light.

7. A unit according to claim 6, wherein said image sensing element and said optical low-pass filter are integrated.

5 8. A unit according to claim 6, wherein said optical low-pass filter unit is adhered to a front surface of a package that encapsulates said image sensing element.

10 9. A unit according to claim 6, wherein said optical low-pass filter is adhered to a front surface of a board on which said image sensing element is mounted and encapsulates said image sensing element.

15 10. A unit according to claim 6, wherein said optical low-pass filter is directly adhered to said image sensing element.

20 11. A unit according to claim 6, wherein said image sensing element has a rectangular image sensing surface, and

an orthogonal projection of an optic axis of one of said at least one birefringence plate onto an entrance or exit surface is substantially parallel to a
25 long side of the image sensing surface.

12. A unit according to claim 6, wherein said

optical low-pass filter comprises:

a first birefringence plate made of a uniaxial single crystal; and

5 a second birefringence plate made of a uniaxial single crystal,

wherein an orthogonal projection of an optic axis of said first birefringence plate onto an entrance or exit surface of the birefringence plate and an orthogonal projection of an optic axis of said second
10 birefringence plate onto the entrance or exit surface of the birefringence plate make substantially 45°.

13. A unit according to claim 12, wherein said image sensing element has a rectangular image sensing
15 surface, and

the orthogonal projection of the optic axis of said first birefringence plate onto the entrance or exit surface of the birefringence plate is substantially parallel to a long side of the image
20 sensing surface, and the orthogonal projection of the optic axis of said second birefringence plate onto the entrance or exit surface of the birefringence plate makes substantially 45° with the long side of the image sensing surface.

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14. An image sensing apparatus comprising:

an image sensing unit of claim 6; and

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an image sensing optical system for guiding
photographing light to said image sensing unit.

15. An apparatus according to claim 14, further
5 comprising a detachable mount.

16. An image sensing unit comprising:

an image sensing element having a rectangular
image sensing surface; and

10 at least one birefringence plate which is inserted
in an optical path of photographing light guided to
said image sensing element, is made of a uniaxial
single crystal that causes birefringence of incoming
rays, and has a refractive index difference of not less
15 than 0.02 for ordinary and extraordinary rays,

wherein said unit satisfies:

$$0.015 < p/d < 0.045 \quad \dots(3)$$

where d is the thickness of said at least one
birefringence plate, and p is the pixel pitch of the
20 image sensing surface in a long side direction.

17. A unit according to claim 16, wherein said
unit satisfies one of:

$$10^\circ < \theta < 27^\circ \quad \dots(1)$$

25 $61^\circ < \theta < 80^\circ \quad \dots(2)$

where θ is the angle an optic axis of the uniaxial
single crystal of said at least one birefringence plate

makes with a normal to a surface of said at least one birefringence plate.

18. A unit according to claim 16, further
5 comprising:

a first birefringence plate made of a uniaxial single crystal; and

a second birefringence plate made of a uniaxial single crystal,

10 wherein an orthogonal projection of an optic axis of said first birefringence plate onto an entrance or exit surface and an orthogonal projection of an optic axis of said second birefringence plate onto the entrance or exit surface make substantially 45°.

15 19. A unit according to claim 18, wherein the orthogonal projection of the optic axis of said first birefringence plate onto the entrance or exit surface is substantially parallel to a long side of the image
20 sensing surface, and the orthogonal projection of the optic axis of said second birefringence plate onto the entrance or exit surface makes substantially 45° with the long side direction of the image sensing surface.

25 20. A unit according to claim 16, wherein the uniaxial single crystal of said birefringence plate is a single crystal of lithium niobate.

21. An image sensing apparatus comprising:
an image sensing unit of claim 16; and
an image sensing optical system for guiding
photographing light from an object to said image
sensing unit.

22. An optical low-pass filter comprising:
a first birefringence plate made of a single
crystal of lithium niobate; and
a second birefringence plate made of a single
crystal of lithium niobate,
wherein an orthogonal projection of an optic axis
of said first birefringence plate onto an entrance or
exit surface and an orthogonal projection of an optic
axis of said second birefringence plate onto the
entrance or exit surface point to different directions,
and all the birefringence plates of said optical
low-pass filter are made of a single crystal of lithium
niobate.

23. A filter according to claim 22, wherein the
orthogonal projection of the optic axis of said first
birefringence plate onto the entrance or exit surface
and the orthogonal projection of the optic axis of said
second birefringence plate onto the entrance or exit
surface make substantially 45°.

24. A filter according to claim 22, wherein when said first and second birefringence plates are adhered, a dielectric thin film having an anti-reflection effect of rays in a visible wavelength range at an interface
5 between the adhesive and each birefringence plate is added to a surface of the birefringence plate.

25. A filter according to claim 22, wherein said filter satisfies one of:

10 $10^{\circ} < \theta_0 < 27^{\circ}$

$61^{\circ} < \theta_0 < 80^{\circ}$

where θ_0 is the angle an optic axis of at least one of said first and second birefringence plates makes with a normal to an entrance or exit surface of the
15 birefringence plate.

26. A filter according to claim 22, further comprising:

a third birefringence plate made of a single
20 crystal of lithium niobate,

wherein the orthogonal projection of the optic axis of said first birefringence plate onto the entrance or exit surface and the orthogonal projection of the optic axis of said second birefringence plate
25 onto the entrance or exit surface make substantially 45° , and the orthogonal projection of the optic axis of said first birefringence plate onto the entrance or

exit surface and an orthogonal projection of an optic axis of said third birefringence plate onto the entrance or exit surface make substantially 90°.

5 27. A filter according to claim 26, wherein said first, second, and third birefringence plates are arranged in turn from a light entrance side, and said filter satisfies:

$$D1 \cong D3 > D2$$

10 where D1, D2, and D3 are respectively the separation distances of said first, second, and third birefringence plates at exit surfaces thereof.

15 28. A filter according to claim 27, wherein said filter satisfies one of:

$$10^\circ < \theta_2 < 27^\circ$$

$$61^\circ < \theta_2 < 80^\circ$$

20 where θ_2 is the angle the optic axis of said second birefringence plate makes with a normal to an entrance or exit surface of a plane-parallel plate.

29. An image sensing unit comprising:

an image sensing element; and

25 an optical low-pass filter of claim 22, which is inserted in an optical path of photographing light guided to said image sensing element, and causes birefringence of the photographing light.

30. A unit according to claim 29, wherein said image sensing element has a rectangular image sensing surface, and

5 an orthogonal projection of an optic axis of one of the plurality of birefringence plates onto an entrance or exit surface is substantially parallel to a long side of the image sensing surface.

31. A unit according to claim 29, wherein an
10 orthogonal projection of an optic axis of said first birefringence plate onto an entrance or exit surface and an orthogonal projection of an optic axis of said second birefringence plate onto the entrance or exit surface make substantially 45°.

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32. A unit according to claim 31, wherein said image sensing element has a rectangular image sensing surface, and

20 an optic axis of one of said first and second birefringence plates is substantially parallel to a long side of the image sensing surface.

33. A unit according to claim 32, further comprising:

25 a first birefringence plate in which an orthogonal projection of an optic axis of a single crystal makes an angle of substantially 45° with a long side

direction of the image sensing surface; and

a third birefringence plate made of a single crystal of lithium niobate,

wherein the orthogonal projection of the optic axis of said first birefringence plate onto the entrance or exit surface and the orthogonal projection of the optic axis of said second birefringence plate onto the entrance or exit surface make substantially 45°, and the orthogonal projection of the optic axis of said first birefringence plate onto the entrance or exit surface and an orthogonal projection of an optic axis of said third birefringence plate onto the entrance or exit surface make substantially 90°.

34. A unit according to claim 33, wherein said unit satisfies:

$$D1 \cong D3 > D2$$

where D1, D2, and D3 are respectively the separation distances of the first, second, and third birefringence plates at exit surfaces thereof.

35. A unit according to claim 34, wherein said first, second, and third birefringence plates are arranged in turn from a light entrance side, and said unit satisfies one of:

$$10^\circ < \theta_2 < 27^\circ$$

$$61^\circ < \theta_2 < 80^\circ$$

where θ_2 is the angle the optic axis of said second birefringence plate makes with a normal to an entrance or exit surface of a plane-parallel plate.

5 36. A unit according to claim 29, wherein at least
one birefringence plate satisfies one of:

$$10^\circ < \theta_0 < 27^\circ$$

$$61^{\circ} < \theta_0 < 80^{\circ}$$

where θ_0 is the angle an optic axis of one of the plurality of birefringence plates made of a lithium niobate single crystal makes with a normal to an entrance or exit surface of a plane-parallel plate.

37. A unit according to claim 29, wherein said
15 image sensing element and said optical low-pass filter
are integrated.

38. A unit according to claim 29, wherein said optical low-pass filter unit are adhered to a front surface of a package that encapsulates said image sensing element.

39. A unit according to claim 29, wherein said optical low-pass filter is adhered to a front surface of a board on which said image sensing element is mounted and encapsulates said image sensing element.

40. A unit according to claim 29, wherein said optical low-pass filter is directly adhered to said image sensing element.

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41. An image sensing apparatus comprising:
an image sensing unit of claim 29; and
an image sensing optical system for guiding
photographing light from an object to said image
sensing unit.